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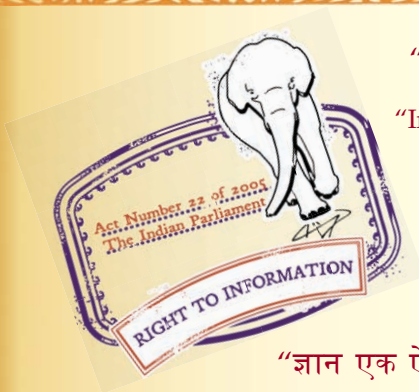
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IS 13263 (1992): Test Methods of Plasma Equipment for Electroheat Applications [ETD 17: Industrial Electroheating Equipment]



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(Reaffirmed 2003)

IS 13263 : 1992

भारतीय मानक

विद्युत उष्मा अनुप्रयोगों के लिए प्लाज्मा उपस्कर
की परीक्षण पद्धतियाँ

Indian Standard

TEST METHODS OF PLASMA EQUIPMENT FOR
ELECTROHEAT APPLICATIONS

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Industrial Electroheating Equipment Sectional Committee had been approved by the Electrotechnical Division Council.

This standard covers the test methods for the plasma equipments for electroheat installations.

In formulating this standard, considerable assistance has been derived from the following IEC Publication issued by the International Electrotechnical Commission:

IEC Pub 680 (1980) Test Methods of Plasma Equipment for Electroheat Applications.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

TEST METHODS OF PLASMA EQUIPMENT FOR ELECTROHEAT APPLICATIONS

1 SCOPE

1.1 This standard specifies methods of test for:

- a) spraying, cutting and welding equipment using plasma torches; and
- b) solid, liquid and gaseous charge heating equipment using plasma torches.

2 REFERENCES

2.1 IS 9029 : 1978 'Methods of tests for batch furnaces with metallic heating resistors, is a necessary adjunct to this standard.

3 DEFINITIONS

3.1 Plasma Heating

Method of heating using the thermal and/or electrical properties of ionized gas.

3.2 Plasma

An ionized gaseous medium in which the electron and ion densities are approximately equal.

3.3 Arc Plasma

Plasma which is ionized by an arc discharge.

3.4 Plasmogenic Gas

A gas or vapour which is or may be ionized to form a plasma.

3.5 Inductive Plasma

Plasma which is ionized through the effect of an alternating electromagnetic field of inductive origin.

3.6 Plasma Generating Torch (Plasma Torch)

An appliance in which a gas is changed into plasma by electrical energy transfer prior to its emission.

3.7 Nozzle

A device which constitutes an electrode which is used to contract the stream of plasma, in order to increase its energy density.

3.8 Nozzle Channel Length

Length of the cylindrical part of the nozzle.

3.9 Non-Transferred Indirect Arc Plasma Torch

A plasma torch in which the main arc is generally maintained between two or more internal electrodes.

3.10 Transferred (or Direct) Arc Plasma Torch

A plasma torch in which the main arc is maintained between the internal electrode and an external electrode (workpiece).

3.11 Superimposed Arc Plasma Torch

A non-transferable arc plasma torch in which the emitted plasma carries a superimposed electric current between the nozzle and an external electrode (workpiece).

3.12 Plasma Flame

Flow of plasma from the nozzle of the plasma torch or from an appliance making use of non-transferred arc discharge.

3.13 Plasma Jet

Plasma in which the speed plays an important part in the process, emitted from the nozzle of an arc plasma torch, making use of non-transferred arc discharge.

3.14 Plasma Spraying

Coating process in which a material introduced in the form of powder or wire and melted in a plasma jet is sprayed into a surface.

3.15 Plasma Cutting

Cutting by localized melting followed by the ejection of the molten material by the effect of a plasma jet.

3.16 Plasma Welding

Gas (generally inert gas) welding process, with or without filler metal, in which the energy is supplied by a plasma jet.

3.17 Plasma Furnace

A heating appliance comprising a chamber which is heated by one of several plasma torches.

3.18 Plasma Melting Furnace

Furnace in which melting effect is achieved using plasma torches.

3.19 Open-Hearth Type Plasma Furnace

Plasma furnace lined with refractory material designed to process large volumes of molten material.

3.20 Crystallizer Type Plasma Furnace

Plasma remelting equipment in which metal is remelted into a vertical or horizontal copper crystallizer.

3.21 Bottom Electrode

Electrode conducting current into the charge of an open-hearth type plasma furnace.

3.22 Equipment for the Control of Plasma Jet Stability and Direction

System enabling the stabilization and directing of plasma jet using electric and magnetic fields.

3.23 Mean Plasma Temperature

Temperature defined on the basis of the measuring method used.

3.24 Cathode

Normally the internal electrode of a direct current arc plasma torch, usually a refractory metal rod eventually cooled (such as tungsten).

3.25 Anode

Normally the nozzle of a direct current non-transferred arc plasma torch, usually made of material (such as copper) having high thermal and electrical conductivity, provided with an orifice and cooled. The workpiece itself acts as anode in the transferred arc plasma torch.

3.26 Vortex

State of flow in which the gas is subject to a helical movement before its transformation into plasma.

3.27 Laminar Plasma Torch

Plasma torch whose operation is characterized by a laminar flow of the plasma jet.

3.28 Turbulent Plasma Torch

Plasma torch whose operation is characterized by a turbulent flow of the plasma jet.

3.29 High-Frequency Ignition Device

A device used in an arc plasma torch to ignite the arc by a high-frequency electric discharge between the electrodes.

3.30 Injection Angle

Angle between the direction of introduction of powder or wire into the plasma jet and the axis of this plasma jet in the direction of flow.

3.31 Kerf Angle

Angle formed by the two cut edges. The included angle is positive if the cut is larger on the face nearest to the torch.

3.32 Normal Operation of a Plasma Torch

Operation characterised by reproducible working conditions defined by the nature of the gas, its rate of flow (l/s or l/min), the current (A), voltage (V) and electrode configuration.

3.33 Specified Current of a Plasma Torch

Maximum current which should be used with a specified gas.

3.34 Useful Power of a Plasma Torch

Difference between the power input to the torch fitted with cooling pipes and the power dissipation in the cooling liquid circuit.

3.35 Specified Power of a Plasma Torch

Maximum power which can be used by a plasma torch for a specified gas.

3.36 Efficiency of a Plasma Torch

Ratio of useful power to active input power.

3.37 Pilot Arc

An arc of low intensity between internal electrodes which is used to initiate the ignition of the main arc and possibly, maintain it.

3.38 Pilot Arc Power

Power required to maintain superimposed current flow in a transferred arc or superimposed arc plasma torch.

3.39 Superimposed Power

Power dissipated by superimposition of a current on one or several plasma jets in a plasma equipment.

3.40 Power Deposition Efficiency

The ratio of the mass of powder consolidated on a substrate agreed upon by the manufacture and the user, to the mass of powder fed to the torch.

4 TYPE AND GENERAL CONDITIONS OF TESTS

4.1 Tests to be Carried Out on Plasma Spraying, Cutting and Welding Equipment

Spraying, cutting and welding equipment comprising one or more plasma torches shall be subjected to the following tests:

4.1.1 Test for Electric Power Unit Characteristics

- Determination of the voltage/current characteristic [see 5.1.1 (a)];
- Measurement of useful power and input power [see 5.1.1 (b)];
- Determination of efficiency [see 5.1.1 (c)]; and
- Measurement of insulation resistance and dielectric strength test [see 5.1.1 (d)].

4.1.2 Tests for Ignition Circuit Characteristics

- a) Measurement of radio interference level [see 5.1.2 (a)]; and
- b) Control of ignition capability in various gases [see 5.1.2 (b)].

4.1.3 Tests for Cooling Circuit Characteristics

- a) Measurement of cooling liquid inlet and outlet temperature as a function of its rate of flow at maximum continuous power of the equipment [see 5.1.3 (a)]; and
- b) Determination of the flow/pressure characteristics [see 5.1.3 (b)].

4.1.4 Test for Gas Circuit Characteristics

Determination of the flow/pressure characteristics of the gas circuit(s) (see 5.1.4).

4.1.5 Tests for Deposited Material Characteristics**4.1.5.1 Tests for powder used**

- a) Determination of range of particle size [see 5.1.5.1 (a)];
- b) Determination of ease of flow [see 5.1.5.1 (b)];
- c) Determination of the carrier gas circuits flow/pressure characteristics [see 5.1.5.1 (c)];
- d) Determination of maximum feed rate as a function of the maximum power of the equipment [see 5.1.5.1 (d)]; and
- e) Determination of the powder deposition efficiency as a function of the powder feed rate (kg/s) and torch powder feed rate (kg/s) and torch powder (kW) [see 5.1.5.1 (c)].

4.1.5.2 Tests for wire

- a) Determination of the wire diameter [see 5.1.5.2 (a)]; and
- b) Determination of maximum feed rate as a function of the maximum power of the equipment [see 5.1.5.2 (b)].

4.1.6 Tests for Plasma Torch Characteristics

- a) Measurement of insulation resistance and dielectric strength tests [see 5.1.6 (a)];
- b) Temperature measurement of accessible parts of the torch [see 5.1.6 (b)];
- c) Noise level measurement under different operating conditions [see 5.1.6 (c)];
- d) Determination of the concentration of possible toxic compounds evolved in normal operation of the torch [see 5.1.6 (d)]; and
- e) Measurement of electrode and nozzle wear [see 5.1.6 (e)].

4.2 Tests to be Carried out on Plasma Heating Equipment

Plasma furnace equipment comprising one or more plasma torches, shall be subjected to the following tests.

4.2.1 Tests for Electric Power Unit Characteristics

The provisions of 4.1.1 shall apply.

4.2.2 Test for Ignition Circuit Characteristics

The provisions of 4.1.2 shall apply.

4.2.3 Test for Cooling Circuit Characteristics**4.2.3.1 Test for torch circuit**

The provisions of 4.1.3 shall apply.

4.2.3.2 Tests for furnace circuit

- a) Measurement of cooling liquid inlet and outlet temperature as a function of the rate of flow at maximum continuous power of the equipment [see 5.2.3.2 (a)]; and
- b) Determination of the flow/pressure characteristics [see 5.2.3.2 (b)].

4.2.4 Tests for Plasma Torch Characteristics**4.2.4.1 Non-transferred and transferred arc operation**

The provisions of 4.1.6 shall apply.

NOTE — Tests under Items (b) and (c) foreseen in 4.1.6 shall be made by agreement between the manufacturer and the user.

4.2.4.2 Tests for superimposed arc operation

- a) Determination of useful superimposed power and superimposed power inputs [see 5.2.4.2 (a)],
- b) Determination of the ratio of superimposed power to pilot arc power [see 5.2.4.2 (b)],
- c) Determination of efficiency [see 5.2.4.2 (c)], and
- d) Measurement of the insulation resistance and dielectric strength test [see 5.2.4.2 (d)].

4.2.5 Tests for Equipment Characteristics**4.2.5.1 Determination of effectiveness of sealing (see 5.2.5.1).****4.2.5.2 Determination of the gas circuit flow/pressure characteristic, excluding gas(es) used by the torch(es) (see 5.2.5.2).****4.2.5.3 Noise level measurement (see 5.2.5.3).****4.2.5.4 Temperature measurement of accessible furnace parts (see 5.2.5.4).**

4.2.5.5 Determination of the concentration of toxic compounds evolved (*see* 5.2.5.5).

4.3 General Test Conditions

The general test conditions shall be as given in IS 9029 : 1978.

5 TEST METHODS

5.1 Tests applicable to spraying, cutting and welding equipment employing a plasma torch(es).

5.1.1 Electric Power Unit Characteristics

a) *Determination of the voltage/current characteristic*

This shall be determined by means of a voltmeter connected to the output terminals of the power unit and an ammeter connected in series with a non-inductive adjustable load. If the plasma torch is used as load, it is advisable to connect the measuring instruments after ignition of the torch, or to exclude them from the ignition circuit;

b) *Measurement of useful power and active input power*

With a dc supply it is usual to define the useful power as the product of voltage multiplied by the current, irrespective of the residual ripple ratio. With an ac supply the useful power shall be measured by means of a wattmeter. For measurement of input power (*see* 4.3);

c) *Determination of efficiency*

The efficiency is the ratio of useful power to active input power;

d) *Measurement of the insulation resistance and dielectric strength tests:*

1) *Measurement of the insulation resistance*

A voltage of 500 V dc shall be applied for 1 min without breakdown:

- i) between the live parts and the accessible metal parts;
- ii) between the live parts and a metal sheet not larger than 200 mm × 100 mm applied to the outer surface of the external parts made of insulating material.

The insulation resistance shall be not less than 2 MΩ.

2) *Dielectric strength test*

A practically sinusoidal voltage of mains frequency 50-60 Hz, the value of which is specified below, is applied for 1 minute.

At the beginning of the test, the voltage applied is less than half of the prescribed value, and is then rapidly raised to the test value.

The specified values are as follows:

- i) Insulation with a rated voltage lower than or equal to 50 V; test voltage: 500 V;
- ii) Installation with a rated voltage U above 50 V; test voltage $2U + 1\,000$ (min 1 500 V).

The test is carried out:

- i) between the contact pieces of the switches in the "open" position;
- ii) between the live parts and the accessible metal parts (depends on the switch construction); and
- iii) between the live parts and a metal sheet applied to the outer surface of the external parts made of insulating material.

NOTE — Certain resistances of the high-frequency circuit which are normally connected to the frame may be disconnected during the test for operational reasons.

Overstress to capacitors which may be incorporated in the installation shall be avoided during the test between the switch contact pieces.

Leakage phenomena which do not cause a voltage drop shall be ignored.

5.1.2 Ignition Circuit Characteristics

a) *Measurement of radio interference level*

The level of radio interference generated by the high-frequency ignition circuit shall be measured in accordance with the regulations in force in the country in which the equipment is to be used. It shall comply with local regulations; and

b) *Control of ignition capability in various gases*

After connecting the ignition circuit to the terminals of adjustable electrodes plasma torch operated with a given type of gas, the electrode spacing shall be varied within the permissible limits and dependent on the torch insulation as specified by the torch manufacturer. At the maximum electrode spacing the gas flow shall be varied till the high-frequency spark has disappeared. This threshold defines the ignition capability of the circuit/torch system.

5.1.3 Cooling Circuit Characteristics

- a) Measurement of cooling liquid inlet and outlet temperature as a function of its rate of flow and of the maximum continuous power of the equipment.

The cooling water temperature difference shall be measured at the terminals of the torch inclusive of the hoses. If thermoelectric sensors such as thermocouples or thermistors are used, they shall be electrically insulated from the cooling liquid. The measurements shall be made at the rate and pressure recommended by the torch manufacturer.

b) Determination of the flow/pressure characteristics

The pressure gauge shall be placed at the inlet of the cooling circuit pipeline of the torch inclusive of the pipes. The flow shall be measured either volumetrically or by means of a flowmeter inserted in the cooling circuit ahead of the pressure gauge.

5.1.4 Gas Circuit Characteristics

5.1.4.1 Determination of the flow/pressure characteristics of the gas circuit(s)

The gas flow is measured in cubic metres per minute. The ratio of gas pressure and flow shall be determined by means of a pressure gauge placed at the inlet of the torch, pipes included, and a flowmeter inserted in the circuit ahead of the pressure gauge. The measurements shall preferably be taken on a torch operating with the currents and gas flows recommended by the manufacturer.

5.1.5 Deposited Material Characteristics

5.1.5.1 Powder used in tests

a) Determination of range of particle size

Standard type sieves shall be used. The latter are usually measured in micrometres.

NOTE — This method is applicable only to powders with particle sizes greater than 20 μm . Below this limit, the method should be as stated by the powder manufacturer.

b) Determination of ease of flow

It is determined as the ratio of the powder quantity and time of flowing through a gauge orifice (for example, diameter 3 mm, length 5 mm).

c) Determination of the carrier gas circuit flow/pressure characteristics

This test shall be carried out using a powder suitable for the design and application of the installation. Generally, powdered alumina (99.5 percent Al_2O_3) with a range of particle size suitable for the maximum flow and torch powder specified by the torch manufacturer is suitable. The pressure gauge shall be

inserted ahead of the powder feeding system and the flowmeter ahead of the pressure gauge.

d) Determination of maximum feed rate as a function of the torch powder

This test shall be carried out using a powder suitable for the design and applications of the installation. Generally, powdered alumina (99.5 percent Al_2O_3) with an appropriate range of particle size is suitable.

The maximum powder feed rate shall be determined before obstruction of the nozzle of pipes.

e) Determination of deposition efficiency

This test shall be carried out using a powder suitable for the design of the installation. Generally, powdered alumina (99.5 percent Al_2O_3) with a range of particle size as specified by the manufacturer is used. The torch useful power and the gas flow shall be determined at the same time as the powder flow in order to obtain optimum efficiency. The mass of powder deposited and the mass fed to the torch shall be measured and an efficiency determined as the ratio of these two masses according to 3.40.

5.1.5.2 Wire

a) Determination of diameter

The wire diameter shall be measured by conventional means with the permissible limits specified by the torch manufacturer.

b) Determination of maximum feed rate as a function of the maximum power of the equipment

This test shall be carried out using a stainless steel wire with the diameter specified by the torch manufacturer. The maximum wire feed rate shall be determined before obstruction of the torch.

5.1.6 Plasma Torch Characteristics

a) Measurement of the insulation resistance and dielectric strength test

i) Measurement of the insulation resistance

The plasma torch insulation resistance shall be measured under the same conditions as that specified in item (d) of 5.1.1 relating to electric power unit characteristics, the cooling circuit being in operation.

The insulation resistance shall be not less than 2 M for the parts provided with functional insulation, or 7 M for

parts with reinforced insulation and likely to be held by hand when using the torch.

ii) *Dielectric strength test*

This test is carried out under the same conditions as that in item (d) of 5.1.1 with an additional test between live parts and the external parts having reinforced insulation (a metal sheet is applied to the outer surface of the external parts of insulating material). Test voltage: 4 000 V.

In addition to these requirements, the plasma torches shall satisfy tests carried out at the high-frequency ignition voltage with the maximum admissible electrode spacing specified by the manufacturer, no high-frequency current shall flow between parts of the torch other than electrodes.

b) *Temperature measurement of accessible parts of the plasma torch*

The surface temperature at different points of accessible parts of the torch shall be measured when conditions of steady state at the maximum continuous power of the equipment have been obtained during operation by a conventional method.

c) *Noise level measurement under different operating conditions*

These measurements shall comply with the safety regulations prescribed by the statutory authorities in which the area the equipment have been obtained during operation by an equipment is to be used.

d) *Determination of concentration of toxic compounds evolved*

These measurements shall comply with the safety regulations prescribed by the statutory authorities in the area in which the equipment is to be used.

e) *Measurement of electrode and nozzle wear*

Electrode and nozzle wear may be expressed by metal weight (mg) per unit time (h) during operating condition established by the agreement between the manufacturer and the user. It shall be determined by weighing the electrodes and measuring the gas volume used.

NOTE — Operating conditions may be continuous or intermittent; the volume of gas flow and current density affect electrode and nozzle wear.

5.2 Tests on Plasma Heating Equipment

5.2.1 Electric Power Supply Characteristics

The provisions of 5.1.1 shall apply.

5.2.2 Ignition Circuit Characteristics

The provisions of 5.1.2 shall apply.

5.2.3 Cooling Circuit Characteristics

5.2.3.1 Torch circuit

The provisions of 5.2.3 shall apply.

5.2.3.2 Furnace circuit

a) *Measurement of cooling liquid inlet outlet temperatures as a function of rate of flow and equipment power*

The cooling liquid temperature difference shall be measured at the inlet and outlet terminals of each of the equipment elements, including pipes. If thermoelectric sensors such as thermocouples or thermistors are used, they shall be electrically insulated from the cooling liquid. The measurements shall be made at the rate of flow and pressure recommended by the equipment manufacturer.

b) *Determination of the flow/pressure characteristics*

The pressure gauge shall be placed at the inlet of the cooling circuit of each of the equipment components. The flow shall be measured either volumetrically or by means of a flowmeter inserted in the circuit ahead of the pressure gauge.

5.2.4 Plasma Torch Characteristics

5.2.4.1 Non-transferred arc operation

The provisions of 5.1.6 shall apply.

5.2.4.2 Superimposed arc operation

a) *Determination of useful superimposed power and superimposed active power input*

The useful superimposed power is that defined in 3.39. With a dc supply, the superimposed power input is the product of the voltage across cable terminals multiplied by the current, irrespective of the residual ripple ratio.

NOTE — With an ac supply the superimposed active power input shall be measured by means of one or more wattmeters.

The power dissipation in the cooling circuit is the product of cooling liquid flow rate q (kg/s) multiplied by increase of temperature difference (K) between the cooling circuit inlet and outlet caused by the superimposition of current and the specific heat C_p (J/kg K) of the cooling liquid (for example, for water, $C_p = 4\,200$ J/kg K):

$$P(\text{kW}) = C_p (\text{J/kg K}) \times (K) \times q(\text{kg/s}) \times 10^{-3}$$

b) *Determination of the ratio of the superimposed power to pilot arc power*

This ratio is equal to the ratio of total superimposed active power input to total pilot arc power input.

c) *Determination of efficiency*

The efficiency of a plasma torch defined 7c) in 3.36.

The powers to be taken into account for the calculation of efficiency shall be the sum of pilot arc and superimposed powers.

d) *Measurement of the insulation resistance and dielectric strength test*

The provisions of 5.1.1 (d) shall apply.

5.2.5 Equipment Characteristics

5.2.5.1 Determination of effectiveness of sealing

If the furnace is to be used for the manufacture of toxic products, it shall meet the standard sealing requirements prescribed by the statutory authorities of the area in which the furnace is to be used. Tests for sealing shall include the detection of chlorofluorine products as a vacuum furnaces.

5.2.5.2 Determination of the gas circuit flow/pressure characteristics, excluding gas used for the torches

The gas flow shall be measured in cubic met

per second or cubic metres per hour. The relation between gas pressure and flow rate shall be measured by means of a pressure gauges placed at the equipment circuit inlet, including pipes, and a flowmeter inserted in the circuit before the pressure gauge.

On the flow/pressure characteristics, the point corresponding to the specified power and specified gas flow given by the manufacturer shall be noted.

5.2.5.3 Noise level measurement

The noise level shall be measured in compliance with the safety regulations prescribed by the statutory authorities in the area in which the furnace is to be used.

5.2.5.4 Temperature measurement of accessible furnace parts

This measurement shall be made during normal operation of the furnace, at maximum continuous power, using a conventional surface temperature measuring method at various points in condition of steady state.

5.2.5.5 Determination of the concentration of toxic compounds evolved

The measurements shall comply with the safety regulations prescribed by the statutory authorities in the area in which the furnace is to be used.

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